10/581632
AP3 Rec'd PCT/PTO 02 JUN 2006



# Coriolis mass flowmeter

## Claim of Priority

This application is the national phase filing of International Application No. PCT/EP2004/013559 filed on November 30, 2004 published as WO2005/054790 which designated at least one country other than the United States of America ("the PCT Application") and the PCT Application claims the priority of German Application No. 103 56 383.0 filed on December 3, 2003 ("the German Application") and the contents of the PCT Application and the German Application are relied upon and incorporated herein by reference in their entirety, and the benefit of priority under 35 U.S.C. 119 is hereby claimed.

The invention relates to a Coriolis mass flowmeter which has at least one pipe through which the mass flows, which pipe can be made by an excitation unit to undergo mechanical vibration as an oscillating element, the oscillating behavior of which, changing in dependence on the mass flow, can be sensed by means of at least one sensor for determining the mass flow. In addition, the invention also relates to a method for operating such a Coriolis mass flowmeter.

A Coriolis mass flowmeter serves for measuring the flow of fluid masses on the basis of fluid mechanics and is used in installations in which the precision of the mass flow is relevant, such as in refineries for example.

Such a Coriolis mass flowmeter is already known from DE 3007361 C3, which is of the same generic type. The Coriolis mass flowmeter, which in this case has a symmetrical construction, substantially comprises an

inflow flange and outflow flange, which establish the connection between inflow and outflow pipe legs and external inflow and outflow pipes. A measuring pipe connects the inflow and outflow pipe legs in such a way that a shape similar to the Greek letter $\Omega$ is obtained for the Coriolis mass flowmeter.

Configurations with double, parallel pipe runs are also known. At the connecting points there are in each case an inflow recording point and outflow recording point. Each Coriolis mass flowmeter of the type of interest here is based on the following physical principle:

An excitation unit makes the measuring pipe vibrate. The oscillations sensed at the inflow and outflow recording points are of the same phase. When the fluid mass flows through the Coriolis mass flowmeter, it undergoes accelerated oscillatory deflections, which produce a Coriolis force. The originally sinusoidal, uniform oscillation of the pipe then undergoes influences of the Coriolis force distributed along the measuring pipe, which causes a phase shift for the inflow and outflow recording points. The oscillation phases and oscillation amplitudes are recorded at the inflow and outflow recording points by means of inflow and outflow sensors and fed to an evaluation unit. The magnitude of the phase shift is a measure of the mass flow.

How the phase shift relates to the mass flow is determined for each Coriolis mass flowmeter by a calibration. The magnitude of the phase shift is dependent on the resilience and mass of the pipe run. The resilience is in turn dependent on the pipe geometry and the material rigidity. The pipe geometry describes for example the nominal diameter and the wall thickness of the pipe.

As long as the material data and the pipe geometry remain unchanged, the calibration carried out retains its validity. If, however, the geometry of the pipe - for example the wall thickness - changes, the calibration once carried out is no longer valid.

A disadvantage of the known Coriolis mass flowmeter is that an abrasive and/or corrosive flowing fluid mass can attack and erode the wall thickness of the pipe run here. Such wear changes both the nominal pipe diameter and the pipe wall thickness, and consequently the resilience of the pipe changes. Such a change of the pipe resilience causes a changed phase shift for the same mass flow and gives an erroneous measure of the mass flow.

A further disadvantage is the increase in material fatigue as a result of the reduction in the wall thickness of the pipe run and consequently, in an extreme case, component failure in the form of fatigue ruptures.

The object of the invention is therefore to provide a means of making it possible to predict the respective mechanical condition of the pipe run in order to prevent such component failure.

The object is achieved on the basis of a Coriolis mass flowmeter according to the preamble of claim 1 in conjunction with its characterizing features. The dependent claims reproduce advantageous developments of the invention.

The object is achieved according to the invention by providing that, to determine the current state of wear of the pipe, the excitation unit imparts a single oscillatory pulse to the pipe, the oscillatory response of which is sensed by means of the at least one sensor

and used by a downstream evaluation unit as a basis for calculating the current damping constant of the pipe and comparing this with a stored, original damping constant of the pipe when it was new.

This solution has the advantage that the individual, characteristic curve of the Coriolis mass flowmeter, and consequently the decay constant, of the pipe run are sensed and can be used as a measure of the operating reliability of the component. This means can be used both as a detector for the respective operating state of the eroded and/or corroded Coriolis mass flowmeter concerned and as verification for the abrasion or corrosion resistance of the Coriolis mass flowmeter concerned. This means takes on special significance in particular with regard to manufacturer liability and risk analysis, required in guidelines for pressure instruments, and avoidance of risks.

It is best if a mass flow is not taking place when the single oscillatory pulse is imparted to the pipe by the excitation unit, in order that the measurement of the state of wear is not influenced by disturbances. The damping behavior of the Coriolis mass flowmeter may, however, also being recorded under simultaneous mass flow. The disturbing mass flow can subsequently be eliminated by a computational program, which makes allowance for the fluid data such as the viscosity, the density, the oscillating conditions of the measuring pipe and the operating temperature. The advantage of this way of sensing the damping behavior of the Coriolis mass flowmeter is that operation in a continuously operating installation does not have to be interrupted.

Instead of the electromagnetically excitable steel measuring pipe that is usually used, an electromagnetically neutral measuring pipe with at

least one excitation aid may also be used. The advantage of the alternative material for the measuring pipe is that, depending on the fluid mass and its corrosive or abrasive property, an appropriate material can be used.

Ceramic materials may be used for the measuring pipe. The advantage of ceramic materials for the measuring pipe is the resistance of these materials to abrasion. Plastics may also be used for the measuring pipe. The advantage of plastics for the measuring pipe is the resistance of these materials to corrosion.

Further means that improve the invention are provided by the subclaims or are described in more detail below together with the description of a preferred exemplary embodiment of the invention on the basis of the figures, in which:

Figure 1 shows a schematic side view of a Coriolis mass flowmeter, and

Figure 2 shows a decay curve of a damped oscillating system.

According to Figure 1, a Coriolis mass flowmeter includes, inter alia, an inflow flange 1, which together with an inflow pipe leg 3, a measuring pipe 9, an outflow pipe leg 4 and an outflow flange 2, forms a pipe arrangement which has a shape similar to the Greek letter Ω and through which the fluid mass to be measured flows. The inflow flange 1 connects an external supply flow pipe to the inflow pipe leg 3. The outflow flange 2 connects an external outflow pipe to the outflow pipe leg 4.
The inflow flange 1 and the outflow flange 2 serve as a holder for the Coriolis mass flowmeter. An excitation unit 8 makes the Coriolis mass flowmeter vibrate by a

single excitation. The damped oscillating behavior of the Coriolis mass flowmeter is recorded in the presence of a mass flow as a characteristic curve at a recording point 5 by means of a sensor 15, which is connected to an electronic evaluation unit 10. The evaluation unit 10 determines the characteristic curve of the Coriolis mass flowmeter from the data for the current state.

The diagram represented in Figure 2 shows a typical characteristic curve which was recorded in the description of Figure 1 at the recording point 5.

The x axis t shows the time and the y axis A the amplitude.

For the envelope which forms a tangent to the vertices of the oscillation: $A = c \cdot e^{-\delta t}$

where

c = constant

and

$\sigma$ = decay constant.

These two constants are characteristic and act as a kind of fingerprint of the respective operating state of the Coriolis mass flowmeter concerned. This makes it possible to document the progression of the changes of the constants and draw a conclusion as to the abrasion or corrosion behavior. This means can be used to verify the abrasion or corrosion resistance of a Coriolis mass flowmeter.